Protective Devices characteristics

1. Fuses

Fuses operate because the fuse element is the 'weak link' in the circuit, so that overcurrent will melt it and break the circuit. The time taken for the fuse link to break the circuit (to 'blow') varies depending on the type of fuse and on the characteristic of the device. The time/current characteristic of a typical fuse is shown in {Fig 1(a)}. Curves for other types and ratings of fuses are shown in {Figs 1 to 3.}. The figures are adapted from Appendix 3 of the BS 7671.

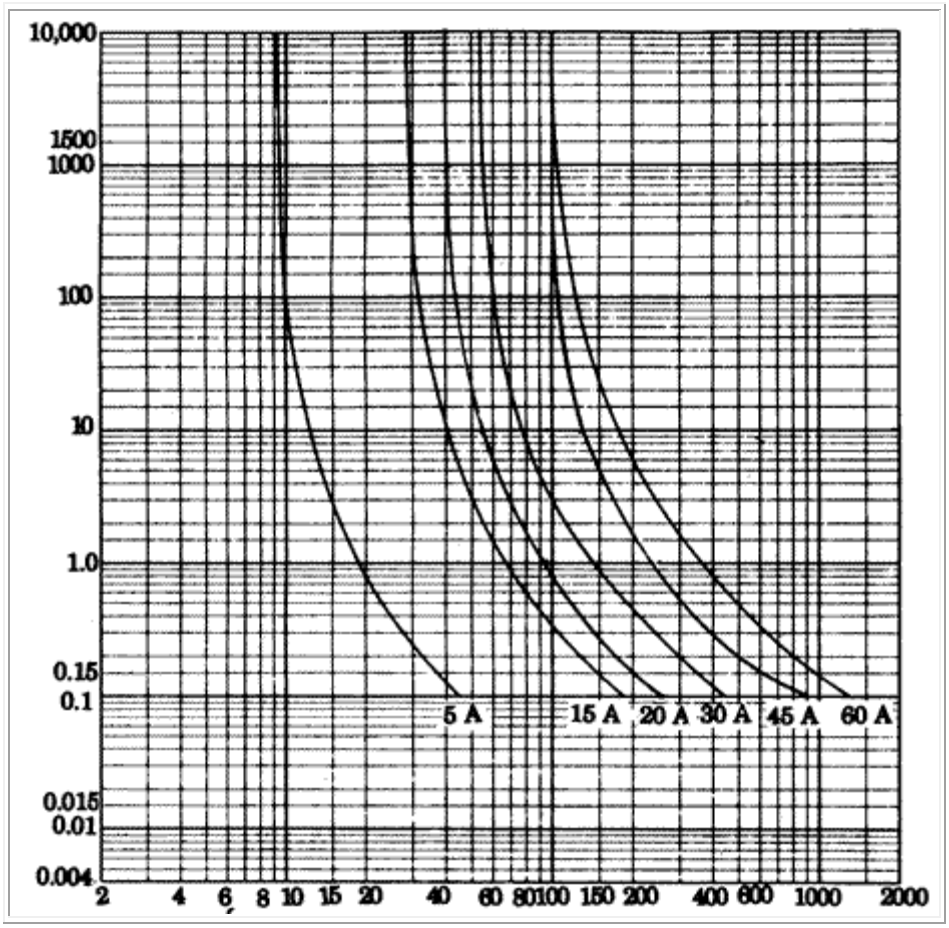

Fig .1 Time/current characteristics of semi-enclosed fuses to BS 3036.

Where the current carried is very much greater than the rated value (which is usually associated with a fault rather than with an overload) operation is usually very fast. For small overloads, where

the current is not much larger than the rated value, operation may take a very long time, as indicated.

A graph with linear axes would need to be very large indeed if the high current/short time and the low current/long time ends of the characteristic were to be used to read the time to operate for a given current. The problem is removed by using logarithmic scales, which open out the low current and short time portions of the scales, and compress the high current and long time portions.

This means that the space between two major lines on the axes of the graph represents a change of ten times that represented by the two adjacent lines. In other words, a very much increased range of values can be accommodated on a graph of a given size.

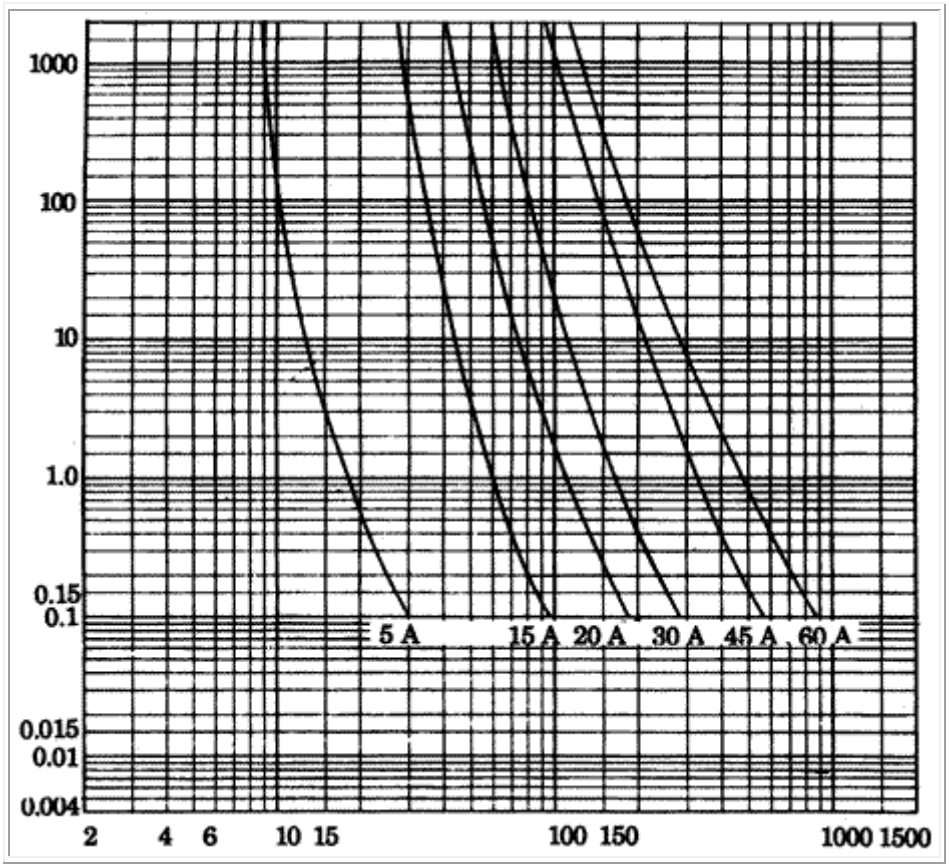

Fig 2. Time/current characteristics of cartridge fuses to BS 1361.

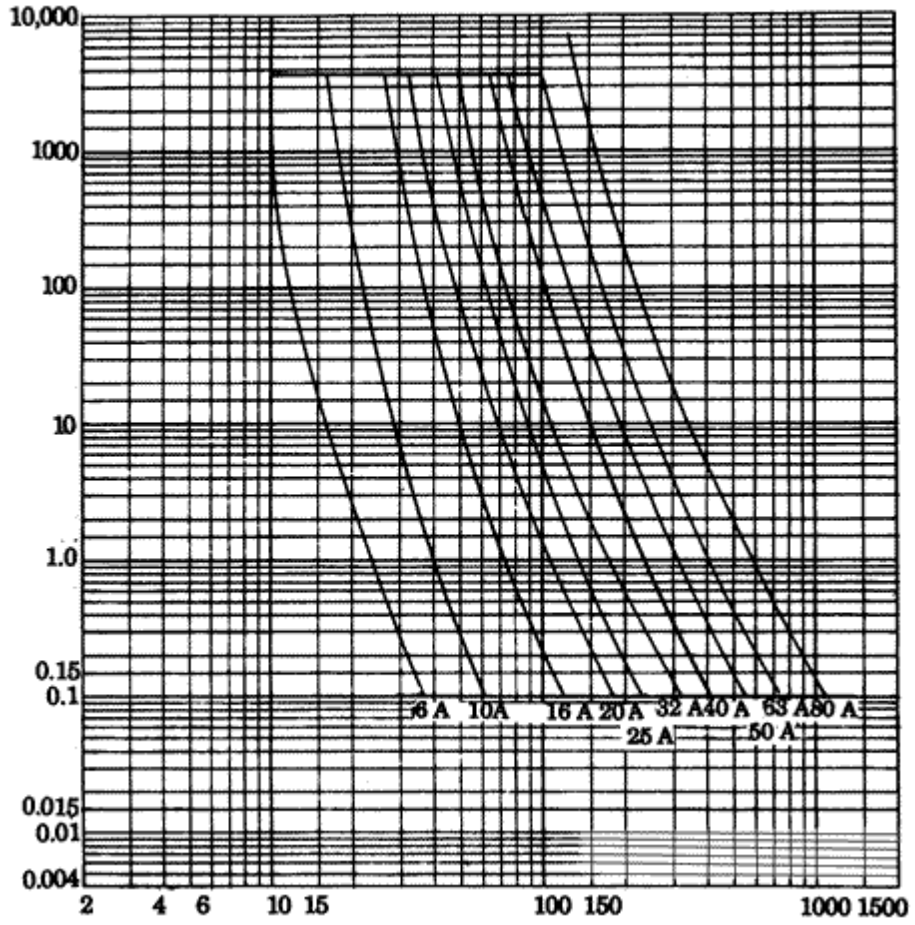

Fig 3 Time/current characteristics of cartridge fuses to BS 88 Part 2

Rewirable (semi-enclosed) fuses to BS 3036 may still be used, but as they can easily have the wrong fuse element (fuse wire) fitted and have low breaking capacity, they are not recommended for other than small installations. Where used, they are subject to the derating requirements which are explained in, The diameter of copper wires for use as elements in such fuses is shown in Table 1.

Table 1 Sizes of tinned copper wire fuse elements (from [Table 53A] of BS 7671)	
Fuse element rating (A)	*Wire diameter (mm)*
3	0.15
5	0.20
10	0.35
15	0.50
20	0.60
25	0.75
30	0.85
45	1.25
60	1.53

2. Circuit breakers

Circuit breakers operate using one or both of two principles. They are:

1). Thermal operation relies on the extra heat produced by the high current warming a bimetal strip, which bends to trip the operating contacts,

2). Magnetic operation is due to the magnetic field set up by a coil carrying the current, which attracts an iron part to trip the breaker when the current becomes large enough.

It must be remembered that the mechanical operation of opening the contacts takes a definite minimum time, typically 20 ms, so there can never be the possibility of truly instantaneous operation. All circuit breakers must have an indication of their current rating.

Types of circuit breaker

There are many different technologies used in circuit breakers and they do not always fall into distinct categories. Types that are common in domestic, commercial and light industrial applications at low voltage (less than 1000 V) include:

- MCB (Miniature Circuit Breaker)—rated current not more than 100 A. Trip characteristics normally not adjustable. Thermal or thermal-magnetic operation. Breakers illustrated above are in this category.
- MCCB (Moulded Case Circuit Breaker)—rated current up to 1000 A. Thermal or thermal-magnetic operation. Trip current may be adjustable.
- ACB (Air circuit breaker) – rated current up to 4000 A .Thermal and magnetic operation. Trip current adjustable.

Miniature circuit breakers have fixed ratings but moulded case types can be adjusted.

There are many types and ratings of moulded case circuit breakers, and if they are used, reference should be made to supplier's literature for their characteristics. Miniature circuit breakers are manufactured in fixed ratings from 5 A to 100 A for some types,

Short circuit ratings for the newer types will be a minimum of 3 kA and may be as high as 25 kA.

The time/current characteristics of all types of circuit breakers are shown in Figs 4 to 6. .

For example, a Type C MCB has a multiple of 10 (from Table 2) so a 30 A device of this type will operate over the time range of 0.04 s to 5 s at a current of 10 x 30 A = 300 A.

Table 2 Operating time ranges and current multiples for MCBs over fixed current section of characteristic

MCB Type	*Range of operating times (s)*	*Current multiple of rating*
B	0.04 to 13	x5
C	0.04 to 5	x10
D	0.05 to 3	x20

Table 3 shows a comparison of the three main types of protective device in terms of cost, whilst Table 4 compares the available types of MCB.

Table 3 A comparison of types of protective device

Semi-enclosed fuses	*HBC fuses*	*Miniature circuit breakers*
Very low initial cost	Medium initial cost	High initial cost
Low replacement cost	Medium replacement cost	Zero replacement cost
Low breaking capacity	Very high breaking capacity	Medium breaking capacity

Fig .1 show that about 53 A is needed to ensure the operation of a 30 A fuse after 10,000 s, giving a ratio of 53/30 or 1.77. For re-wirable fuses, the Regulations require that the fuse current rating must not exceed 0.725 times the rating of the smallest cable protected. Considering the 30 A cable protected by the 32 A miniature circuit breaker above, if a rewirable fuse replaced the circuit breaker, its rating must not be greater than 0.725 x 30 or 21.8 A.

Table 4 Comparison of miniature circuit breaker types

Type	Will not trip in	Will trip in	Typical application
	100ms at rating	100ms at rating	
B	3 x	5 x	General purpose use (close protection)
C	5 x	10 x	Commercial and industrial applications with fluorescent fittings
D	10 x	50 x	Applications where high in-rush currents are likely (transformers, welding machines)

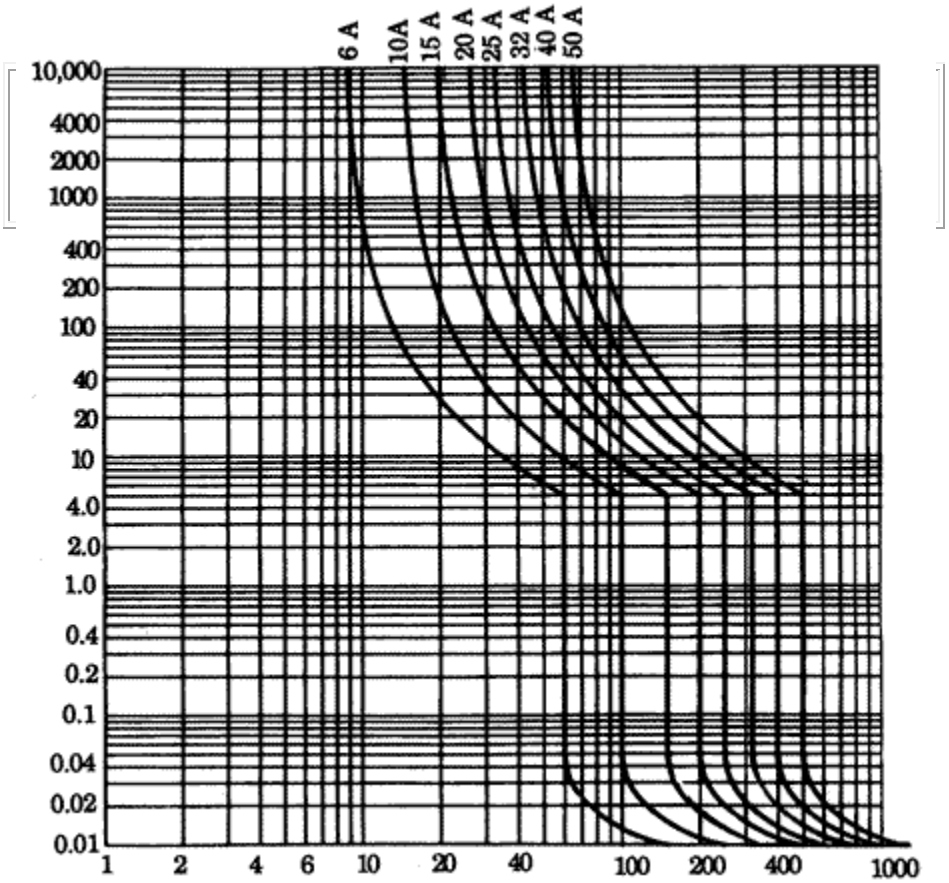

Fig 4 Time/current characteristics for some miniature circuit breakers Type C.

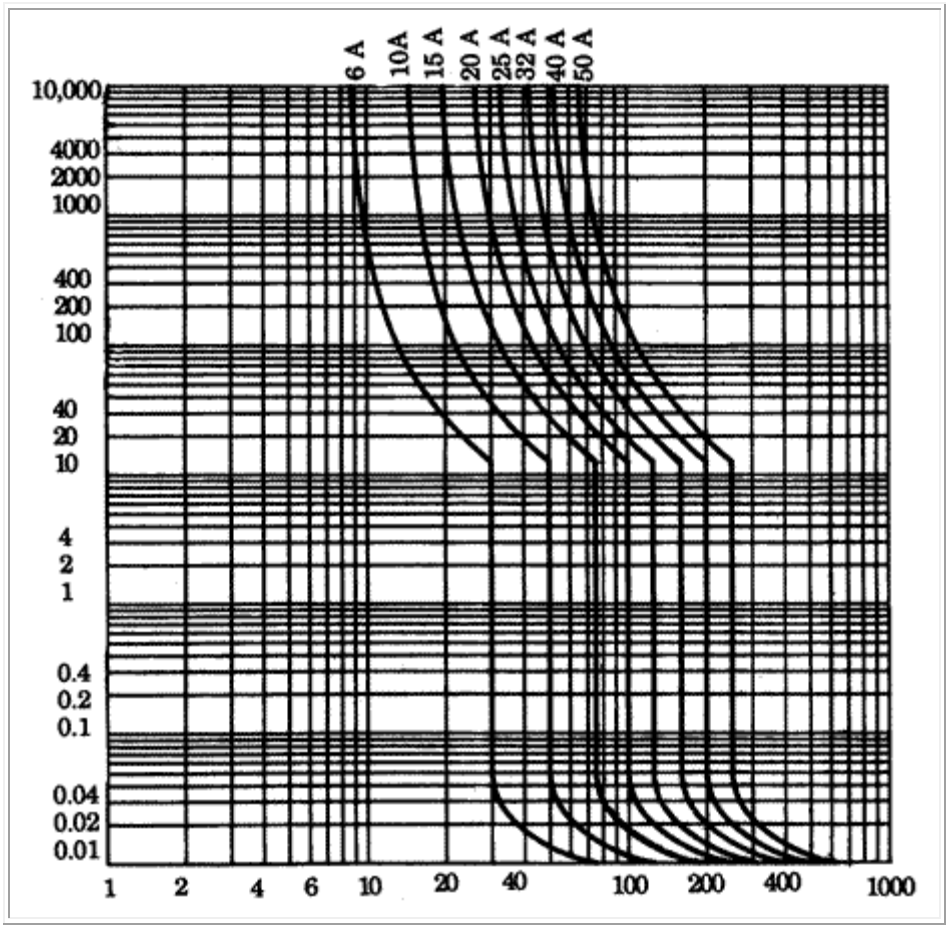

Fig 5 Time/current characteristics for some miniature circuit breakers Type B.

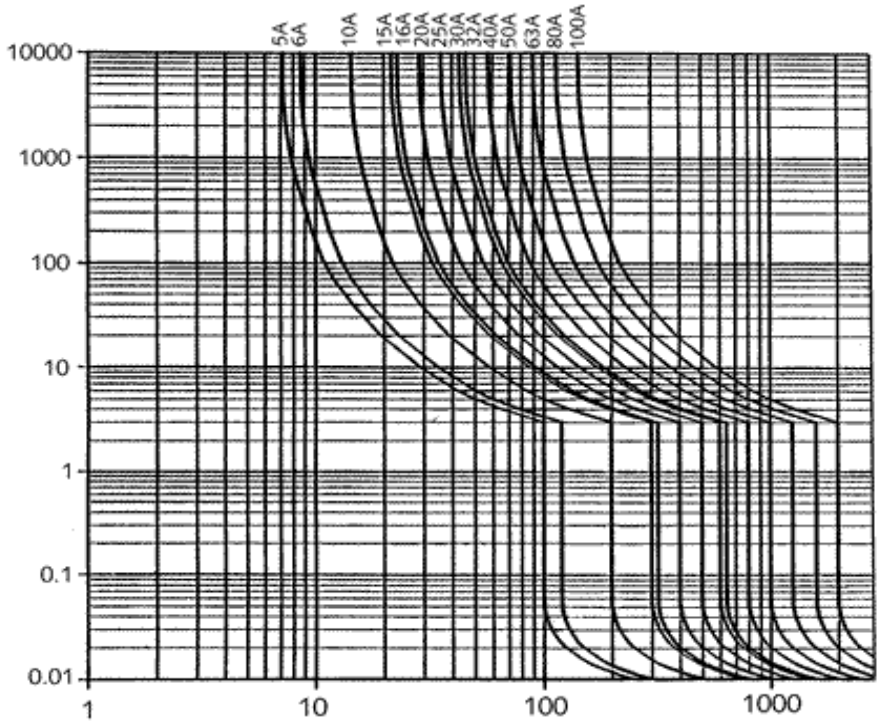

Fig. 6 Time/current characteristics for some miniature circuit breakers Type D.

Protecting conductors

The prime function of overload protection is to safeguard conductors and cables from becoming too hot. Thus the fuse or circuit breaker rating must be no greater than that of the smallest cable protected. Reference to the time/current characteristics of protective devices {Figs 1 to 6} shows that a significantly greater current than the rated value is needed to ensure operation.

Thus, the current at which the protective device operates must never be greater than **1.45** times the rating of the smallest cable protected. For example, consider a cable system rated at 30 A and protected by a miniature circuit breaker type C, rated at 32 A. Reference to Fig.5 shows that a prolonged overload of about 38 A will open the breaker after about 10^4 seconds (about two and a half hours). The ratio of operating current over rated current is thus 38/30 or 1.27, significantly lower than the maximum of **1.45**. All circuit breakers and HBC fuses listed in will comply with the Regulations as long as their rating does not exceed that of the smallest cable protected.

Semi-enclosed (rewirable) fuses do not operate so closely to their ratings as do circuit breakers and HBC fuses. For example, the time/current characteristics of {Fig .1} show that about 53 A is needed to ensure the operation of a 30 A fuse after 10,000 s, giving a ratio of 53/30 or 1.77. For rewirable fuses, the Regulations require that the fuse current rating must not exceed 0.725 times the rating of the smallest cable protected. Considering the 30 A cable protected by the 32 A miniature circuit breaker above, if a rewirable fuse replaced the circuit breaker, its rating must not be greater than 0.725 x 30 or 21.8 A.

Figure 7 shows part of a system to indicate how protection could be applied to conductors with reduced current carrying capacity.

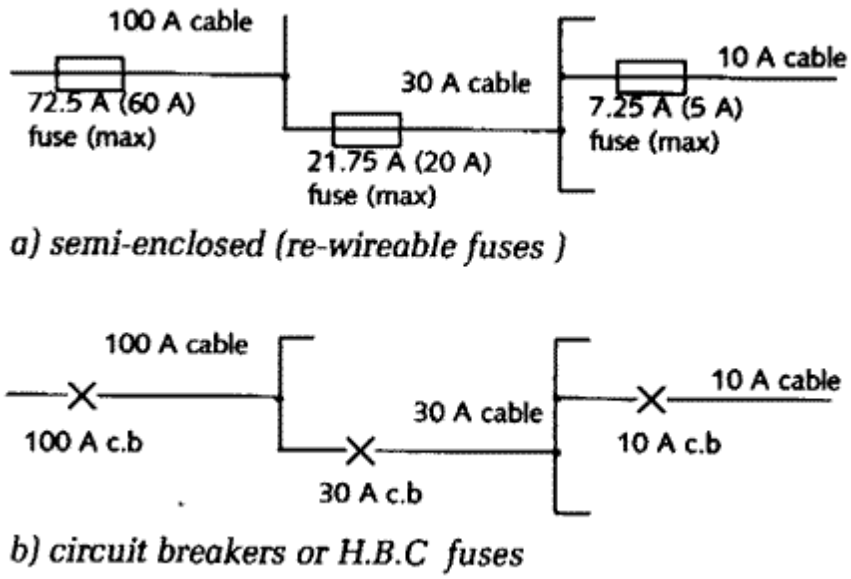

Fig.7 Position and rating of devices for overload protection

- In fact, the calculated fuse sizes for {Fig.7a)} of 72.5 A, 21.75 A and 7.25 A are not available, so the next lowest sizes of 60 A, 20 A and 5 A respectively must be used.
- It would be unwise to replace circuit breakers with semi-enclosed fuses because difficulties are likely to arise. For example, the 5 A fuse used as the nearest practical size below 7.25 A is shown in {Fig.1} to operate in 100 s when carrying a current of 10 A. Thus, if the final circuit is actually carrying 10 A, replacing a 10 A circuit breaker with a 5 A fuse will result in the opening of the circuit. The temptation may be to use the next semi-enclosed fuse size of 15 A, but that fuse takes nearly seven minutes to operate at a current of 30 A. Clearly, the cable could well be damaged by excessive temperature if overloaded.
- All phase conductors must be protected, but attention must be paid to the need to break at the same time all three line conductors to a three-phase motor in the event of a fault on one phase, to prevent the motor from being damaged by 'single-phasing'. Normally the neutral of a three phase system should not be broken, because this could lead to high voltages if the load is unbalanced. Where the neutral is of reduced size, overload protection of the neutral conductor may be necessary, but then a circuit breaker must be used so that the phases are also broken.